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Pacific Southwest Region

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A BIOLOGICAL EVALUATION OF WHITE PINE BLISTER RUST ON THE SEQUOIA NATIONAL FOREST

Report No. 84-22

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ABSTRACT

A white pine blister rust incidence and impact survey was conducted on the Sequoia National Forest in order to determine the rate of new blister rust establishment and the levels of damage caused by the disease. Previously unreported blister rust infection centers were found at 17 of 41 locations surveyed. Of 377 sugar pines examined at the 17 sites, 36% were infected, but only 14% were lethally infected. Three infection centers on the Hot Springs District were intensively examined to determine characteristics of infection. About 6% of the trees at Deep Creek, 33% of the trees at Double Bunk Creek, and 25% of the trees at French Joe Creek were lethally infected. Canker incidence generally decreased from stream bottom to upper slope. Management alternatives discussed include removal of infected trees during sanitation and precommercial thinnings, pruning branches on non-lethally infected trees, and strategies for regenerating sugar pine on low, moderate, and high hazard sites.

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INTRODUCTION

The history of white pine blister rust on the Sequoia National Forest is relatively recent. The disease first entered northern California from Oregon in 1929, and has since advanced southward through the Sierra Nevada. The known southern limit remained at Dodge Ridge on the Stanislaus National Forest from 1944 until 1968, when the location of the rust was extended 150 air miles south to the Mountain Home area in Tulare County. The newly found centers at Mountain Home had originated in 1961 and intensified in 1964 and 1967. Additional surveys in 1970 found three small centers in the Tyler Meadow area of the Greenhorn Mountains, an intensification of the rust in Mountain Home State Forest and areas of the Sequoia-Kings Canyon National Park, and the first infection center on the Sierra National Forest. No formal rust surveys were made on the Sequoia National Forest after 1973, but several new rust infection centers have since been reported on the Tule River and Hot Springs Districts.

Current management plans for sugar pine on the Sequoia National Forest include continued use of the species on all areas which the Forest feels are low hazard to rust infection. They will continue to avoid planting sugar pine in high risk areas along stream bottoms, near wet meadows and adjacent to known infection centers.

In 1982 the Forest Pest Management Staff conducted a blister rust incidence and impact survey on the Sierra National Forest (reference Forest Pest Management Report No. 82-44). In July of 1983 a similar survey was conducted on the Sequoia National Forest to obtain additional information on the disease in the southern Sierra. The objectives were to determine 1) the rate of establishment of new blister rust infection centers by scouting for the rust in locations reportedly rust-free in 1972, and 2) the characteristics of infection and levels of damage caused by the rust in known infection centers. The results of these surveys are for use to 1) provide information to the Forest and the Region on locations and impact of the rust disease, 2) to develop strategies for managing the existing and future sugar pine resource, and 3) to determine the need for increasing the selection and breeding of rust resistant sugar pine on the Sequoia National Forest.

BIOLOGY OF THE PEST

White pine blister rust is caused by the fungus Cronartium ribicola, an obligate parasite that attacks sugar and western white pines and several species of Ribes in California. The fungus needs two hosts to survive, spending part of its life on 5-needled pines and the other on Ribes. Infection of pines may result in branch mortality, top kill, and tree mortality.

Spores (aeciospores) are produced by the fungus in the spring on pine bole or branch cankers. They are wind-disseminated to Ribes where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves re-infect Ribes throughout the summer, resulting in an intensification of the rust. Another spore stage forms

on Ribes leaves in the fall. These spores (basidiospores) are wind-disseminated to pines and infect current year needles. Following pine infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, aeciospores are produced on the cankers and are spread to Ribes to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes, its spread from Ribes back to pines is usually limited to a few hundred feet.

Environmental conditions are critical for successful infection and limit the disease in most years. Abundant moisture and cool temperatures favor infection of both hosts, and must coincide with spore dispersal for infection to occur. At least 48 hours with a saturated atmosphere and a temperature near 20°C are needed for infection of pines. In California, the sites where these conditions frequently occur are usually in cool moist areas such as stream bottoms or around meadows. When these years of favorable environmental conditions (wave years) occur, high incidence of infection can result. Wave years have occurred in northern and central California at approximately ten-year intervals in the past. As one moves to less favorable sites for rust, the frequency of wave years decreases.

Active branch cankers enlarge annually as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually reach the bole and form cankers. Bole cankers that girdle the stem kill the tree above the canker. Cankers whose closest margins are more than 24 inches from the bole will usually die out before reaching the bole, and only branch flagging will occur.

INCIDENCE SURVEY

PROCEDURE

Main roads on the five Districts were driven and notes taken on the presence or absence of blister rust. Streams on the Hume Lake, Tule River, and Hot Springs Districts known to have sugar pine, based on 1965 through 1972 blister rust surveys, were marked on a Forest map. Those streams that were crossed by an accessible road or that were within two chains of an accessible road were selected and a portion of them (10 on the Hume Lake, 4 on the Tule River, and 15 on the Hot Springs District) were systematically sampled. Twelve stream-side locations, not marked on earlier maps, were sampled on the Greenhorn District. At each sample point, a one-chain-wide strip was examined on each side of the stream for four chains upstream and four chains downstream. Information, including sugar pine diameter class, presence or absence of rust infection, and, if infected, canker information, including canker class and year of wood infected, were recorded. See the Appendix for definitions of tree diameter classes and blister rust canker classes.

RESULTS AND DISCUSSION

Blister rust was not observed on the Cannell Meadows District. Previously-unreported blister rust infection centers were found at 17 of the 41 locations surveyed on the remaining four Districts (Fig. 1). These included two on the Hume Lake District, three on the Tule River District, nine on the Hot Springs District, and three on the Greenhorn District. The legal descriptions for the 17 locations are listed in the Appendix. Figures 1A, 1B, 1C, and 1D include approximate known locations of blister rust as well as the specific locations sampled during this survey. The approximate locations are based on data and maps from previous surveys, and on observations while traveling roads during this survey.

Only two rust centers were found on the Hume Lake District, despite the abundance of sugar pine and Ribes in micro-sites apparently favorable for the rust. Although it is possible that environmental factors are restricting disease spread, it is more likely that the fungus simply has not been present long enough for spread to have occurred. Aging of cankers indicates that both centers were initiated in the mid-1970's. Centers have been present for about the same period of time in relatively nearby areas of the Sequoia-Kings Canyon National Park. Only three sites were examined on the Tule River District because most of the other suitable streamside sites already were reported throughout the 1970's as infested with the rust. Infection is widespread on the District wherever sugar pine and Ribes occur, especially in the Camp Nelson and Mountain Home areas. The rust has also intensified in known areas and spread to other locations on the Hot Springs District during the 1970's. The rust is present throughout the numerous meadows in the northern part of the District, and is present, but generally at low levels, in the Tyler Meadow area in the southern part of the District. The three locations on the Greenhorn District were probably initiated in the mid-1970's. The location at Bear Creek on the District is the southern most extension of the rust found in the Sierra. These observations, along with aging of cankers, suggests that blister rust on the Sequoia National Forest first occurred in the Mountain Home area in the early 1960's, and is spreading both north and south from there.

Frequencies and characteristics of rust infections are presented in Tables 1, 2 and 3. Of 377 sugar pines examined at the 17 sites, 136 (36%) were infected. Fifty four (14%) of the 377 trees were lethally infected. Lethally infected trees are those with nonprunable bole cankers, lethal nonprunable branch cankers, and/or lethal branch cankers (see Appendix for definitions). The remaining 82 infected trees could be pruned free of existing infections if pruning were done in the first 16 feet of the main stem and in the lower two-thirds of the live crown. The proportion of cankered trees in each diameter class varied from 8% of the trees 26 inches dbh (diameter at breast height) or larger to 49% of the trees from 6.0 to 11.9 inches dbh (Table 3). Although not indicated by the data, observations indicate that both bole and branch cankers can and do occur at higher levels in the tree than expected from observations elsewhere. For example, numerous trees in the Packsaddle Creek area had cankers 30 to 40 feet above ground level.

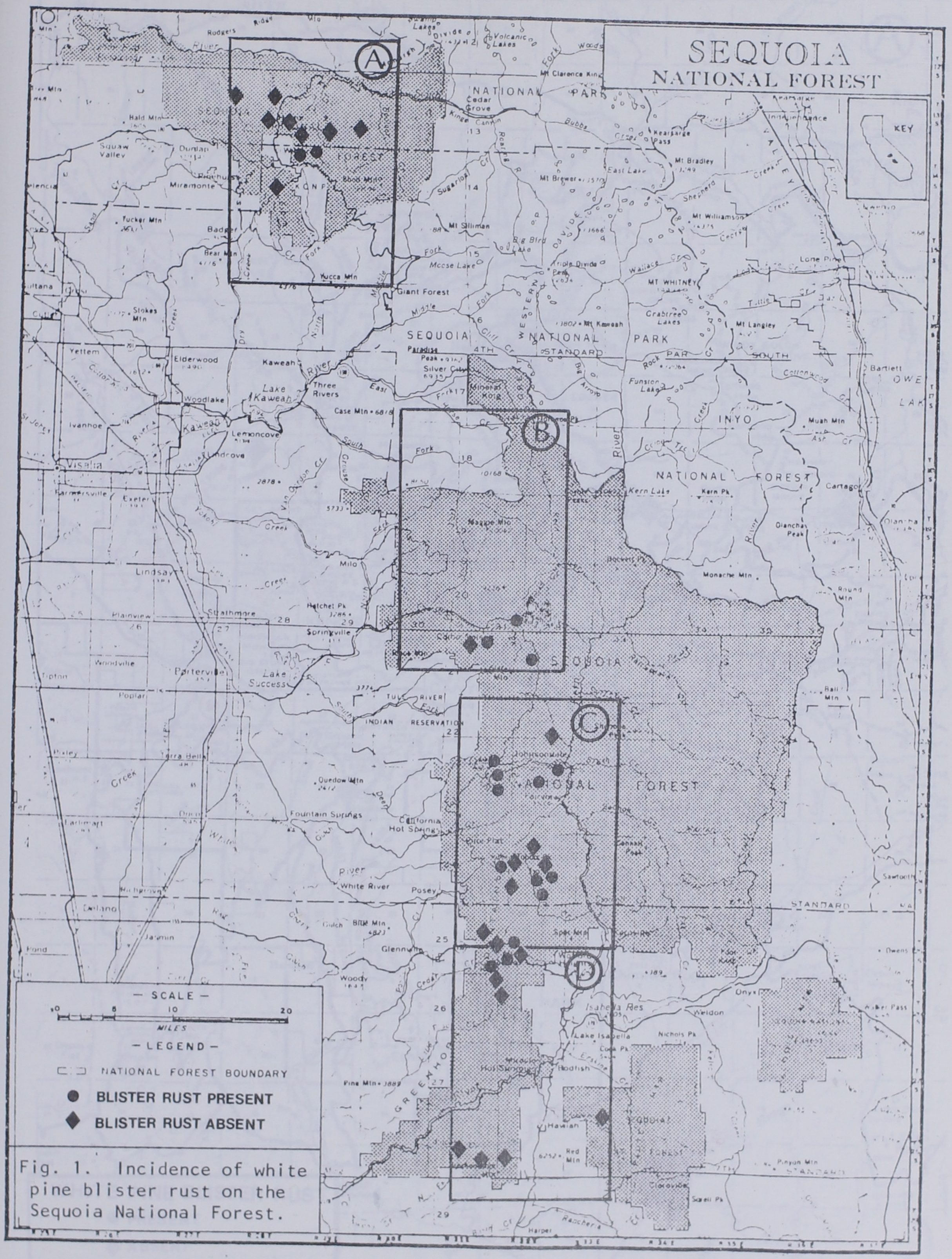
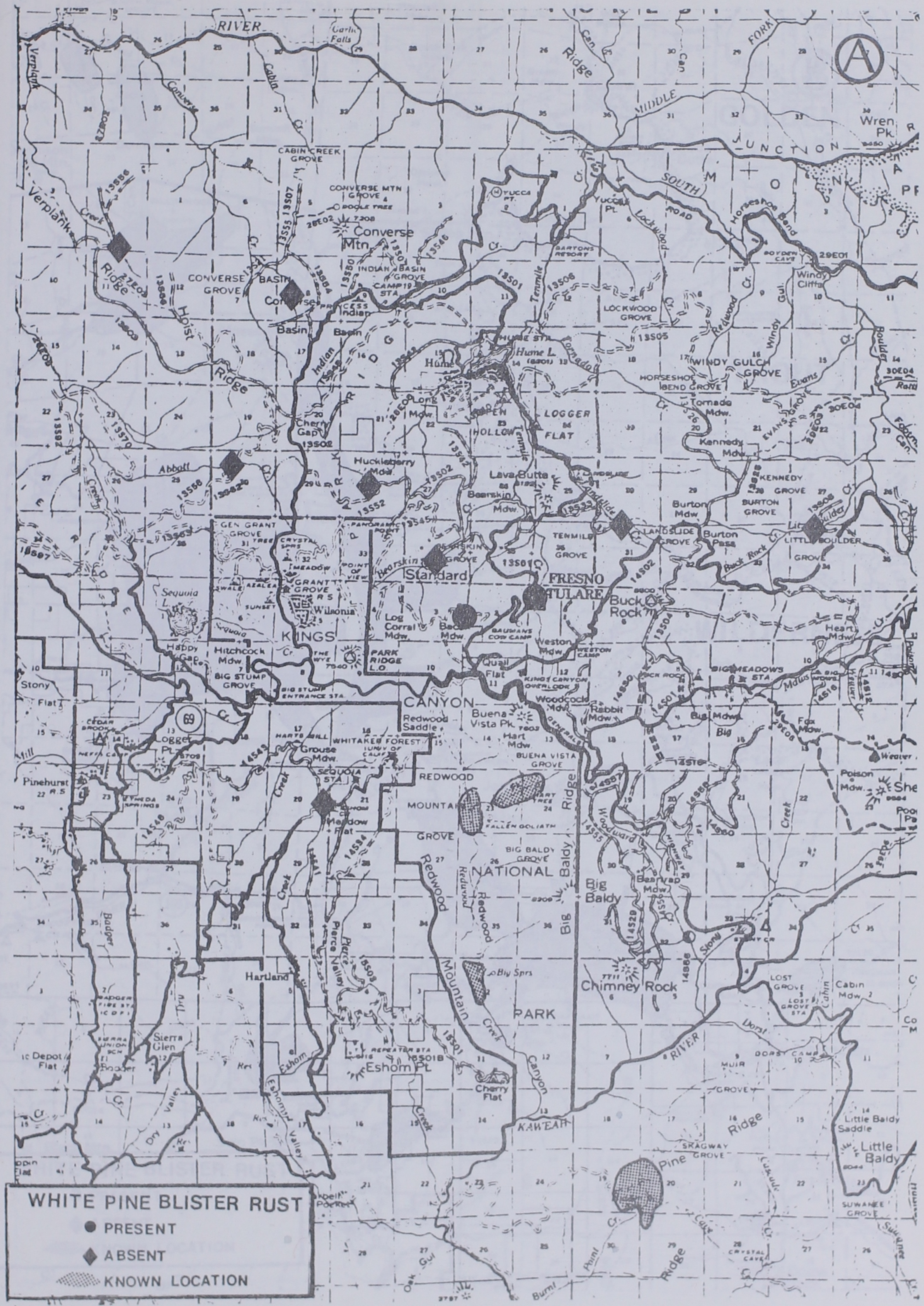


Fig. 1. Incidence of white pine blister rust on the Sequoia National Forest.


RIVER
Garlic Falls
Verplank
Cabin Cr.
Can
Ridge
FORK
MIDDLE
JUNCTION
SOUTH
Wren Pk
CABIN CREEK GROVE
CONVERSE MTN GROVE
Converse Mtn
Yucca Pt.
Lockwood
ROAD
Horseshoe Bend
BOYDEN CAVE
Windy Gulch
CONVERSE BASIN
Hoist
Ridge
INDIAN BASIN GROVE
CAMP 19 STA
Tennile
LOCKWOOD GROVE
Redwood Cr.
Windy Gul.
Hume
HUME STA.
Hume L.
Tornado
WINDY GULCH GROVE
HORSESHOE BEND GROVE
Evans
Boulder
Indian
Cherry Gap
LOGGER FLAT
HOLLOW
Tennile
Tornado Mdw.
Kennedy Mdw.
EVANS GROVE
Abbott
Huckleberry Mdw.
Lava Butte
Bearskin Mdw.
Landslide
KENNEDY GROVE
BURTON GROVE
Burton Mdw.
Burton Pass
LANDSLIDE GROVE
LITTLE BOULDER GROVE
GEN GRANT GROVE
CRYSTAL SPRS
PANORAMIC POINT
POINT OF VIEW
MEADOW
GRANT GROVE
AZALEA
SWALE
SUNSET
Sequoia L.
Wilsonia
Bearskin
Standard
TENMILE GROVE
FRESNO
TULARE
Buck Rock
Buck Rock
Log Corral Mdw.
Bac Mdw.
BAUMANS COW CAMP
Weston Mdw.
WESTON CAMP
Heart Mdw.
KINGS
CANYON
Hitchcock Mdw.
Happy Gap
THE WYE
PARK RIDGE L.O.
BIG STUMP GROVE
BIG STUMP ENTRANCE STA.
Quail Flat
KINGS CANYON OVERLOOK
Woodcock Mdw.
Rabbit Mdw.
BIG MEADOWS STA
Big Mdw.
Fox Mdw.
Weaver
Stony Flat
Redwood Saddle
Buena Vista Pk.
Hart Mdw.
BUENA VISTA GROVE
Lodge Pl.
Grouse Mdw.
WHITAKER FOREST
SEQUOIA STA.
Poison Mdw.
Pinehurst
REDWOOD MOUNTAIN GROVE
Meadow Flat
FALLEN GOLIATH
BIG BALDY GROVE
NATIONAL
Big Baldy
Redwood Creek
Big Baldy Ridge
Bearwad Mdw.
Hoodward
Stony Cr.
Chimney Rock
LOST GROVE
Cabin Mdw.
Harland
Pierce Valley
Mountain Creek
PARK
Sierra Glen
Eshom Pl.
Eshom Valley
Cherry Flat
Canyon Creek
KAWEAH
Dry Valley
RIVER
DORST CAMP
MUIR GROVE
Ridge
Little Baldy Saddle
Little Baldy
SUWANEE GROVE
SRAGWAY GROVE
Pine Ridge
CRYSTAL CAVE
Oak Gul
Burnt Cr.
Paint Cr.
Cahoon Pocket
Pinehurst
Badger
Stony Flat
WHITE PINE BLISTER RUST
PRESENT
ABSENT
KNOWN LOCATION

Mitchell Mdw.
Wet Mdws
South Fork Mdws.
Green Mdw.
Quinn Pk
GOLDEN
Tuohy Mdws.
Summit Mdw.
Dennison
Dennison Mtn.
Windy Gap
Soda Butte
Cyclone Mdw.
Summit L.
Hidden Lks
Sheep Mtn.
DILLONWOOD GROVE
Twin Lks.
Moses Mtn.
Frog Lks.
PECKS CABIN
Maggie Lks.
Maggie Mtn.
TROUT
Alpine
Alpine Mdw.
Mowery Mdw.
Jacobsen Mdw.
Carl L.
Rancheria
STATE FOREST
WILDERNESS
Camp Wisbon
Alder Creek Grove
Jordan Pk
Stick Rock
Log Cabin Mdw.
Junction Mdw.
Upper Loggy Mdw.
Lower Loggy Mdw.
Coffee Mill Mdw.
Deep Mdw.
Camp Nelson
BELKNAP CAMP GROVE
Quaking Aspen Mdw.
White Mdws
Black Mtn.
Solo Pk.
Holby Mdw.
Kramer Mdw.
Ponderosa
Dome Rock
WHITE PINE BLISTER RUST
PRESENT
ABSENT
KNOWN LOCATION

RESERVATION
LOT NO. 37
Mule Pk.
Mule Mdw.
Young Mdw.
Sentinel Pk.
Last Chance Mdw.
Bone Mdw.
Table Mtn.
Capitol Rock
Elephant Knob
Johnsondale
North Cold Spring Pk.
Parker Pk.
Gordon Hills
Devils Den
Buck Slide
Thompson Pk.
Devils Thumb
Skunk Spring Saddle
Corral Hill
Hatchet Pk.
Cold Springs Pk.
Dead Mule Saddle
Eagle Hotel
Lion
Tyler Pk.
Sycamore Gap
Pine Flat
California Hot Springs
George Pk.
Uhl Pocket
Uhl Hill
Pine Mtn.
Capinero Saddle
Quinn Mdw.
Ames Hole
Devils Kitchen
Bear Trap Ridge
Sugarloaf Pk.
Fir Camp Saddle
Bull Run Pk.
Bull Run Mdw.
Tobias Pk.
Tobias Mdw.
Dead Horse Mdw.
Frog Mdw.
Dunlap Mdw.
Baker Pk.
Baker Mdw.
Baker Pt.
Buck Pk.
Twin Pk.
Oak Flat
Carver Pk.
Grist Mill
Idlewild
Poso Park
Peel Pk.
Portuguese Pk.
Portuguese Mdw.
Sand Flat
Sandy Cr.
Bear Dens
Sunday Pk.
Bonna Pk.
Spout Spr.
Pup Mdw
Marshall Mdw.
Panorama Heights
Balance Rock
Durkas Flat
Pinnell Camp
Stone Place (Ruins)
Thompson Camp
Merry Camp
Cougar Camp
Millard Corral
McDermott Camp
Parker Pk Grove
Redwood Corral
Cunningham Grove
Indian Rock
Carver Camp
Indian Potholes
Johnsondale Sta.
Frog Mdw. Sta.
Deer Cr. Mill Grove
Deer Cr. Mill
Starvation Green Grove
White River Summer Home Tract
Spear Cr. Summer Home Tract
Gooseberry Camp
Vinca Camp
Tungstore
Tyler Cr. Fire Sta. (CDF)
Jack Ranch
Vincent Ranch
Franklin Ranch
Poso Sta.
Tiger Flat
Betty Lou
Silver Strand
Black Bamboo
Indian Rock
Burnt Ridge
Speas Ridge
Ryan Ridge
Lion Ridge
Pine Ridge
Bear Trap Ridge
Flat Ridge
Oak Flat Ridge
Valley Ridge
Bald Hills Ridge
Pinnell Camp Ridge
Spring Gap
Stone Place (Ruins)
Sycamore Gap
Tulare
Kern
WHITE PINE BLISTER RUST
PRESENT
ABSENT
KNOWN LOCATION

WHITE PINE BLISTER RUST
PRESENT
ABSENT
KNOWN LOCATION
Shirley Pk
Cooks Pk
Red Mtn
Woodward Pk
Ranger Spr.
Basket Pass
Keyesville
Lake Isabella
Cook Pk
Kernvale
Garfield
Bodfish
Erskine
Ball Mtn
Hooper Hill
Bodfish Pk.
Bald Eagle Pk.
Lightner Pk
Rankin Pk
O'Brien Hill
Havilah
Breckenridge
Squirrel
Munz
Brown Pk
Mountain
Red
ISABELLA
Rattlesnake
Woodward
Black
Bradshaw
Lane
Ridge
Dutchman
Hamlah
Johnson Spr.
Meine Spr.
Deer Spr.
Bog Hole Spr.
Sheep Troughs Spr.
Lightners Flat
Golf Mdw.
Squirrel Mdw.
Munz Mdw.
Brown Mdw.
Spring
Valley
Canal
Creek
Gul.
Cr.
Can.
Ft.
Ridge
Hobo
Lynch
Haight
King
Solomons
North
Thompson
Beartrap
Hobo Hot Spr.
Miracle Hot Spr.
Keysville Hot Spr.
Tungsten Chief
Mine
Main Dam
Spillway
Pioneer
Isabella Auxiliary Dam
Paradise Cove
Mtn. Mesa
Live Oak
Hungary Gulch
Boulder Gulch
Corps of Eng. Houses
Old Likely Mill (site)
White Mill (site)
Peterburg (site)
Mayflower
Lone Star
Davis
Edison
Vaughn Sch.
Double R Ranch
Myers Ranch
Harrington Ranch
Golf Ranch
Knox Ranch
Lazelle Ranch
Brady Ranch
Valley View
Saddle
Burton Mill
Allen
Cannon
Democrat Sta.
Hobo Hot Spr. Sta.
Havilah Sta.
Radio Relay Sta.
TV. Trans.
Breckenridge
Scovern Hot Spr.
Mammoth
White Rock
Golden Olive
Paiute Cypress
Jeanette Cr.
Lauria
Brady
Pettit
Sycamore
Freeman
Greenhorn
Delano Hwy
Ranger Spr.
Evans Ranch
Shirley Pk
Cooks Pk
Red Mtn
Woodward Pk
Basket Pass
Keyesville
Lake Isabella
Cook Pk
Kernvale
Garfield
Bodfish
Erskine
Ball Mtn
Hooper Hill
Bodfish Pk.
Bald Eagle Pk.
Lightner Pk
Rankin Pk
O'Brien Hill
Havilah
Breckenridge
Squirrel
Munz
Brown Pk
Mountain
Red
ISABELLA
Rattlesnake
Woodward
Black
Bradshaw
Lane
Ridge
Dutchman
Hamlah
Johnson Spr.
Meine Spr.
Deer Spr.
Bog Hole Spr.
Sheep Troughs Spr.
Lightners Flat
Golf Mdw.
Squirrel Mdw.
Munz Mdw.
Brown Mdw.
Spring
Valley
Canal
Creek
Gul.
Cr.
Can.
Ft.
Ridge
Hobo
Lynch
Haight
King
Solomons
North
Thompson
Beartrap
Hobo Hot Spr.
Miracle Hot Spr.
Keysville Hot Spr.
Tungsten Chief
Mine
Main Dam
Spillway
Pioneer
Isabella Auxiliary Dam
Paradise Cove
Mtn. Mesa
Live Oak
Hungary Gulch
Boulder Gulch
Corps of Eng. Houses
Old Likely Mill (site)
White Mill (site)
Peterburg (site)
Mayflower
Lone Star
Davis
Edison
Vaughn Sch.
Double R Ranch
Myers Ranch
Harrington Ranch
Golf Ranch
Knox Ranch
Lazelle Ranch
Brady Ranch
Valley View
Saddle
Burton Mill
Allen
Cannon
Democrat Sta.
Hobo Hot Spr. Sta.
Havilah Sta.
Radio Relay Sta.
TV. Trans.
Breckenridge
Scovern Hot Spr.
Mammoth
White Rock
Golden Olive
Paiute Cypress
Jeanette Cr.
Lauria
Brady
Pettit
Sycamore
Freeman
Greenhorn
Delano Hwy
Ranger Spr.
Evans Ranch
26502
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28535
28536
28537
31E72
31E73
31E75
31E78
32E48
32E49
32E81
32E84
33E44
33E45
33E47
33E48
155
178

TABLE 1. Number and percent of sugar pines infected with white pine blister rust at 17 locations on the Sequoia National Forest.

LOCATION	NUMBER OF TREES EXAMINED	INFECTED NO.	INFECTED (%)	LETHALLY INFECTED NO.	LETHALLY INFECTED (%)
HUME LAKE RD					
Bacon Meadow	49	10	(20)	6	(12)
Tenmile Creek	29	7	(24)	0	(0)
TULE RIVER RD					
Peppermint Creek	41	3	(7)	0	(0)
Bear Creek	23	11	(48)	8	(35)
Boulder Creek Tributary	24	11	(46)	4	(17)
HOT SPRINGS RD					
White River Tributary	80	33	(41)	8	(10)
Deep Creek	15	9	(60)	6	(40)
Bull Run Creek Tributary	11	4	(36)	1	(9)
Schultz Creek	29	14	(48)	9	(31)
Packsaddle Creek #1	2	2	(100)	0	(0)
Packsaddle Creek #2	7	4	(57)	4	(57)
Starvation Creek #1	21	9	(43)	1	(5)
Starvation Creek #2	15	1	(7)	0	(0)
Horse Meadow Creek	12	9	(75)	4	(33)
GREENHORN RD					
Bear Creek	11	5	(45)	3	(27)
Shirley Peak	1	1	(100)	0	(0)
Slick Rock Creek	7	3	(43)	0	(0)
TOTAL	377	136	(36)	54	(14)

TABLE 2. White pine blister rust infections, by canker class[1], at 17 locations on the Sequoia National Forest.

LOCATION	BOLE CANKERS		BRANCH CANKERS			
	PRUNABLE	NON PRUNABLE	NON LETHAL	LETHAL PRUNABLE	LETHAL NONPRUNABLE	LETHAL
HUME LAKE RD						
Bacon Meadow	1	6	31	9	0	11
Tenmile Creek	0	0	16	1	1	0
TULE RIVER RD						
Peppermint Creek	0	0	3	1	0	0
Bear Creek	2	3	19	15	7	1
Boulder Creek Trib.	3	3	41	19	2	0
HOT SPRINGS RD						
White River Trib.	0	7	27	8	2	2
Deep Creek	0	6	39	12	3	4
Bull Run Creek Trib.	0	1	5	1	0	3
Schultz Creek	2	6	29	14	6	19
Packsaddle Creek #1	0	0	11	3	0	0
Packsaddle Creek #2	0	0	59	7	5	2
Starvation Creek #1	0	1	33	12	1	0
Starvation Creek #2	0	0	2	1	0	0
Horse Meadow Creek	0	4	59	13	15	0
GREENHORN RD						
Bear Creek	0	2	15	1	4	0
Shirley Peak	0	1	0	1	0	0
Slick Rock Creek	0	1	3	0	0	0
TOTAL	8	41	392	118	46	42

[1] See Appendix B for definitions of canker classes.

Blister rust infections frequently occur in "wave years" -- years especially favorable for infection because of favorable microclimatic conditions during the fall when spores are dispersed from Ribes to pine. A total of 109 cankers were aged at the 17 sites. Although 1975, 1976, and 1977 were years most favorable for infection, cankers were initiated other years as well (Table 4). Infection apparently did not occur until about 1974 on the Hume Lake and Greenhorn Districts, the northern most and southern most districts. In contrast, blister rust was present on some sites on the Tule River and Hot Springs Districts since the 1960's, with 1962 infection at Schultz Creek being the oldest canker we recorded.

IMPACT SURVEY

PROCEDURE

Three blister rust centers on the Hot Springs District -- at Deep Creek, Double Bunk Creek, and French Joe Creek -- were examined intensively to determine characteristics of infection and levels of damage.

The three sites were examined as follows:

1. The approximate limits of infection -- upstream and downstream, and upslope on both sides of the streams -- were determined.

2. One-chain-wide strips, perpendicular to the stream bottom, were examined from ridgetop to ridgetop at 3 to 10 chain intervals, depending on the area of the center. The location of the strips and the distance between them was determined by the desire to obtain sufficient stream bottom, mid-slope, and upper slope plots at each site.

3. Data including tree diameter class, presence of infection, classes of bole and branch cankers (see Appendix), and year of wood infected were recorded for each sugar pine encountered on the strips.

RESULTS AND DISCUSSION

Canker Incidence, by Type and Tree Diameter Class. Twenty percent of the sugar pines examined at Deep Creek, 62% at Double Bunk, and 44% at French Joe Creek had one or more blister rust cankers. Characteristics of the cankers recorded at the three sites are presented in Table 5. The actual numbers of cankers of each category in Table 5 should be interpreted with caution. For example, even though a tree may have one or more prunable bole and branch cankers, it may also have several lethal nonprunable or lethal branch cankers and therefore be lethally infected.

TABLE 4. Number of blister rust cankers by age of canker, at 17 locations on the Sequoia National Forest.

LOCATION	YEAR OF WOOD INFECTED															
	<67	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
HUME LAKE RD																
Bacon Meadow	-	-	-	-	-	-	-	-	-	2	4	4	-	-	-	-
Tenmile Creek	-	-	-	-	-	-	-	-	1	3	2	1	-	-	-	-
TULE RIVER RD																
Peppermint Creek	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-
Bear Creek	-	1	-	3	1	-	3	-	2	1	-	-	-	-	-	-
Boulder Creek Trib.	-	-	-	-	1	1	1	2	2	2	2	-	-	-	-	-
HOT SPRINGS RD																
White River Trib.	-	-	-	-	-	-	-	2	-	6	-	-	-	-	-	-
Deep Creek	-	1	1	-	1	1	-	1	-	-	-	2	-	-	-	1
Bull Run Creek Trib.	-	-	1	-	-	-	-	-	-	1	1	-	-	-	1	-
Schultz Creek	3	-	-	-	-	-	-	2	-	2	2	5	6	1	-	-
Packsaddle Creek #1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Packsaddle Creek #2	-	-	-	-	-	-	-	1	1	-	-	2	2	-	-	-
Starvation Creek #1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Starvation Creek #2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horse Meadow Creek	-	-	-	-	-	1	-	1	-	1	1	-	-	-	-	-
GREENHORN RD																
Bear Creek	-	-	-	-	-	-	-	-	1	2	1	1	-	-	-	-
Shirley Peak	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Slick Rock Creek	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-
TOTAL	6	2	3	3	3	3	4	9	9	23	16	17	8	1	1	1

TABLE 5. Characteristics of blister rust cankers recorded at Deep Creek Double Bunk Creek, and French Joe Creek on the Sequoia National Forest.

LOCATION	NUMBER OF TREES		BOLE CANKERS		BRANCH CANKERS			
	TOTAL	INFECTED	PRUNABLE	NON PRUNABLE	NON LETHAL	LETHAL PRUNABLE	LETHAL NON PRUNABLE	LETHAL
DEEP CREEK	371	73	2	22	143	74	16	22
DOUBLE BUNK CREEK	116	72	5	23	331	74	40	24
FRENCH JOE CREEK	174	76	1	23	756	92	16	55
TOTAL	661	221	8	68	1230	240	72	101

A more accurate reflection of the actual impact of the disease is presented in Figures 2, 3, and 4, where the number and percent of trees lethally infected, by tree diameter class, at each location are presented graphically. Lethally infected trees are those with one or more nonprunable bole cankers, lethal nonprunable branch cankers, or lethal branch cankers.

Canker Incidence, by Topography. Observations in northern California forests, supported by field studies, suggest that the levels of infection along stream bottoms are generally higher than in upland sites. Data for canker incidence at four stream bottom, four mid-slope, and four upper slop plots at each of the three centers are presented in Figure 5. Stream bottom plots were 1 X 1 chain plots that bordered the stream; upper slope plots were those at the end of each transect and from 12 to 24 chains from stream bottom; mid-slope plots were approximately halfway between stream bottom and upper slope.

Canker incidence was generally highest at the stream bottom plots and decreased upslope (Fig. 5). At French Joe Creek for example, 100% of the sugar pine at stream bottom were cankered while only 15% of the sugar pine on upper slope plots (8 to 10 chains from the stream) were cankered.

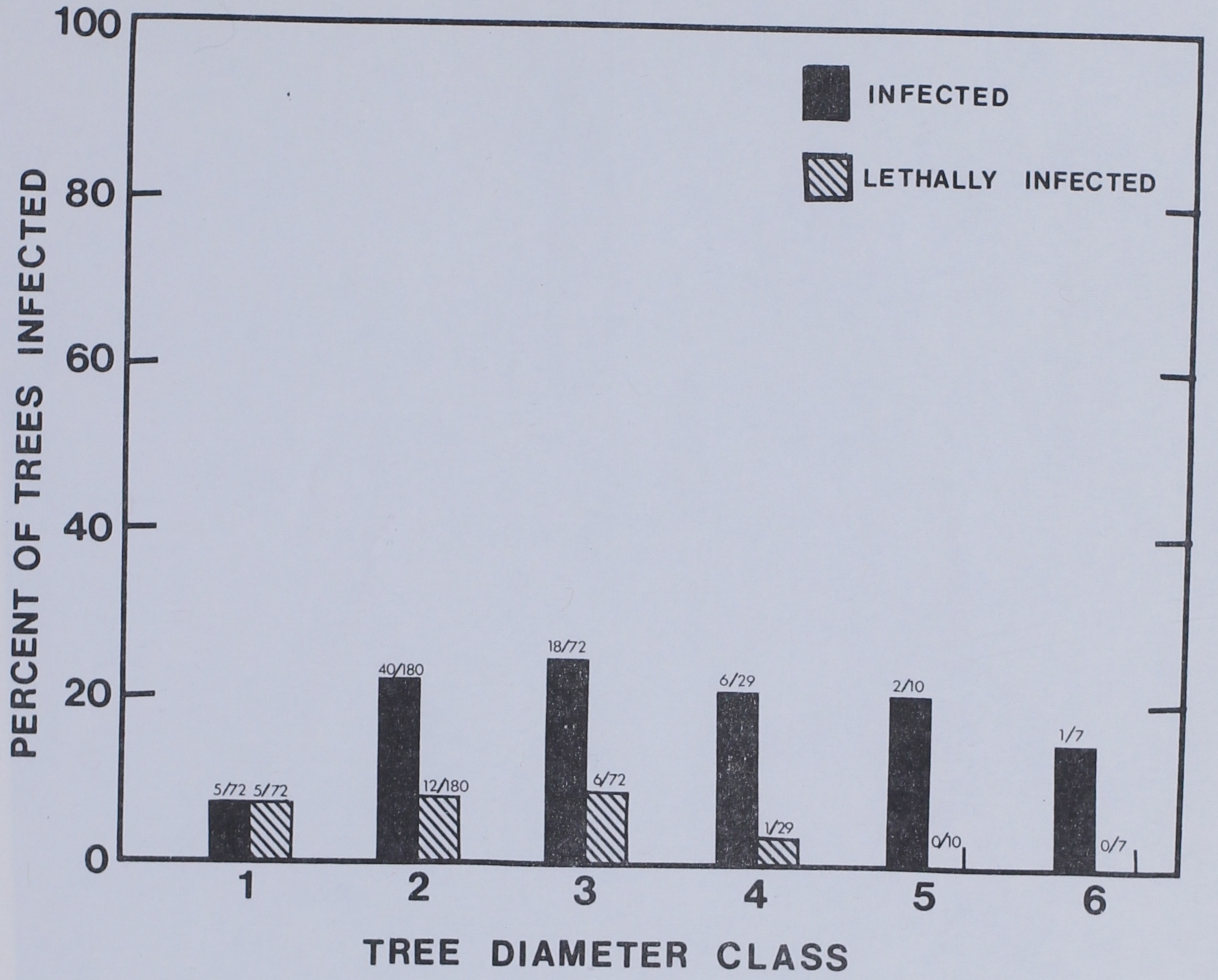

FIGURE 2. Percent of sugar pine infected and lethally infected, by tree diameter class, at Deep Creek. The numbers above each bar are the number of trees in that category/total number of trees. Tree diameter classes are 1 = less than 1 inch dbh, 2 = 1.0 - 5.9 inches, 3 = 6.0 - 11.9 inches, 4 = 12.0 - 17.9 inches, 5 = 18.0 - 25.9 inches, and 6 = 26 inches dbh and greater.

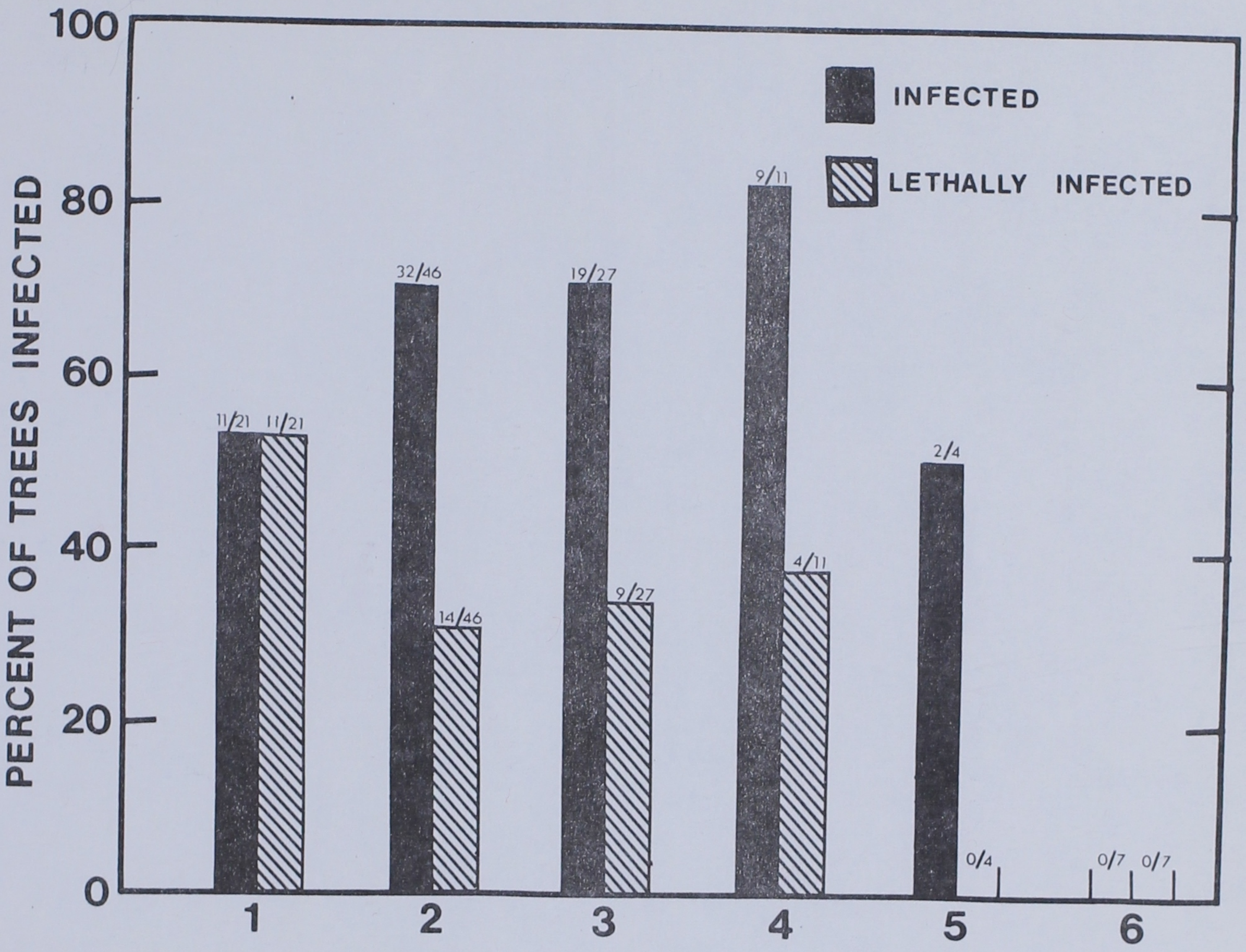

FIGURE 3. Percent of sugar pine infected and lethally infected, by tree diameter class, at Double Bunk Creek. The numbers above each bar are the number of trees in that category/total number of trees. Tree diameter classes are 1 = less than 1 inch dbh, 2 = 1.0 - 5.9 inches, 3 = 6.0 - 11.9 inches, 4 = 12.0 - 17.9 inches, 5 = 18.0 - 25.9 inches, and 6 = 26 inches dbh and greater.

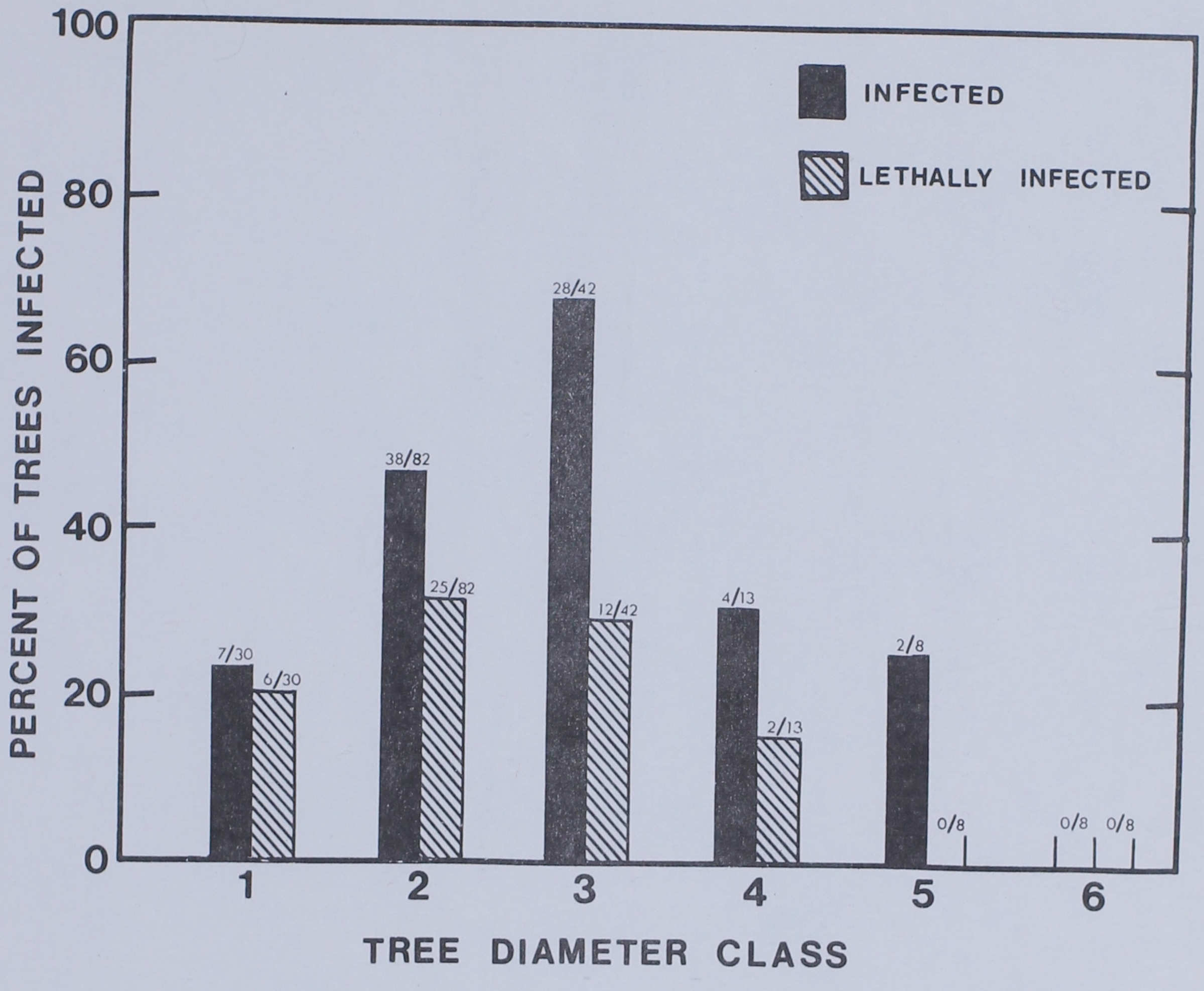

FIGURE 4: Percent of sugar pine infected and lethally infected, by tree diameter class, at French Joe Creek. The numbers above each bar are the number of trees in that category/total number of trees. Tree diameter classes are 1= less than 1 inch dbh, 2 = 1.0 - 5.9 inches, 3 = 6.0 - 11.9 inches, 4 = 12.0 - 17.9 inches, 5 = 18.0 - 25.9 inches, and 6 = 26 inches dbh and greater.

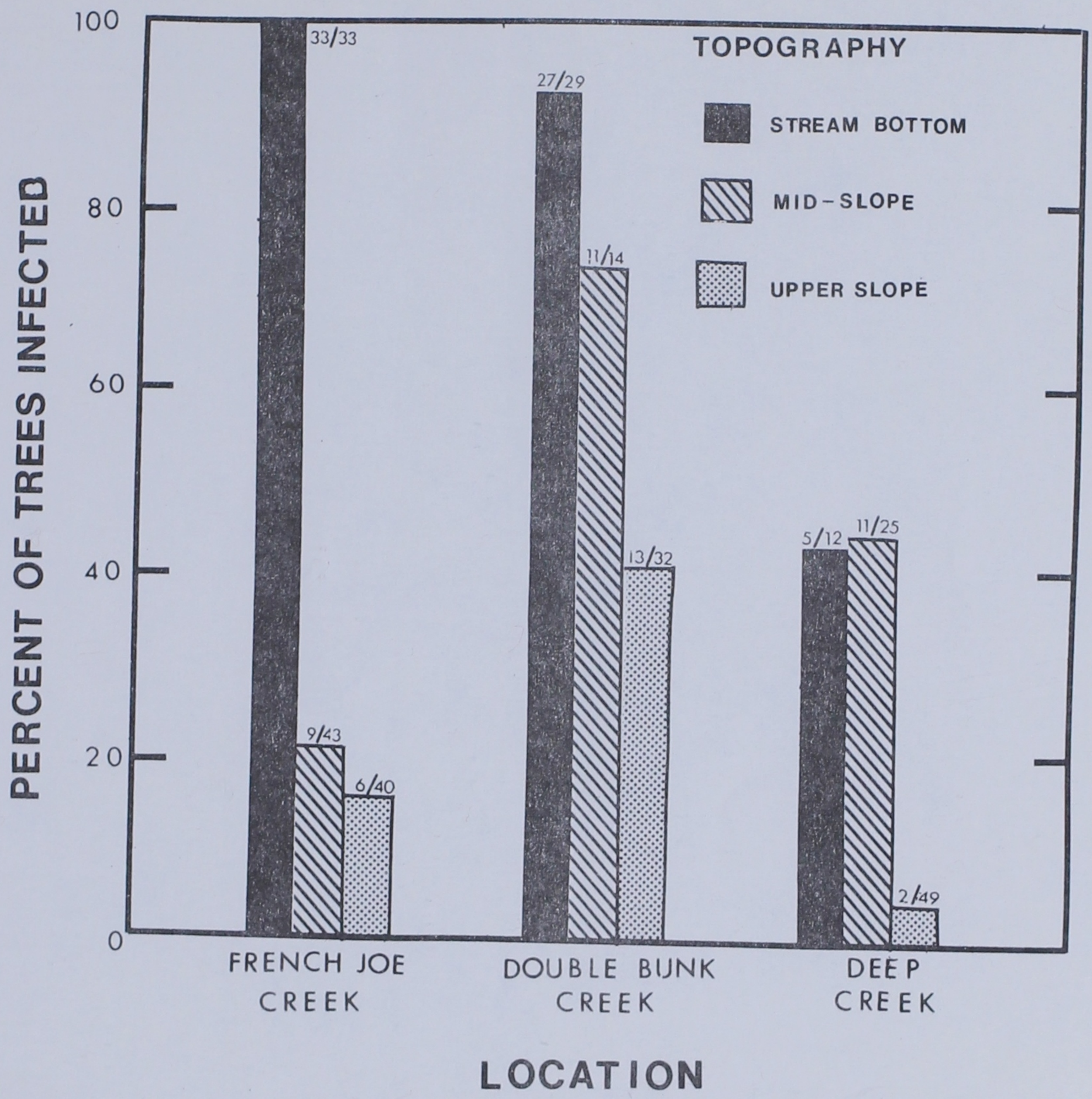

FIGURE 5. Blister rust canker incidence at stream bottom, mid-slop, and upper slope plots at French Joe Creek, Double Bunk Creek and Deep Creek. The numbers above each bar are the number of trees infected/total number of trees.

Canker Incidence, by Year of Wood Infected. Cankers -- 62 at Deep Creek, 62 at Double Bunk Creek, and 31 at French Joe Creek -- were randomly selected and aged in order to determine when infection occurred. Results are presented in Figure 6. Most cankers at the three sites were initiated in the mid-1970's (1973 through 1978), with no one or two years standing out as a wave year. The oldest cankers (1961) were found at Double Bunk Creek and at French Joe Creek.

SUMMARY

White pine blister rust has essentially spread to the southern limits of sugar pine in the Sierra Nevada and is impacting the resource in some local situations. Climatic conditions, as suggested by some earlier workers, are not sufficiently limiting to prevent establishment of the disease in the southern Sierra Nevada. In some areas -- for example, the Mountain Home area (Tule River District) and the numerous meadows east and north of Parker Pass (Hot Springs District) -- levels of rust infection are as high and as damaging as in locations farther north. However, there appear to be some restrictions on the levels and impact of the disease at local areas at the southern limits of sugar pine. For example, the disease has not built up in, or spread significantly from, the Deep Creek/Schultz Creek area (Bull Run Basin, Hot Springs District) since it was first introduced in the 1960's. Also, one would expect rust to be more successful on the Hume Lake District, based on the concentrations of Ribes and sugar pine along the numerous streams and small meadows. In contrast, the rust has spread significantly during the same period of time in the Dinkey Creek area on the Sierra National Forest.

There are several possibilities for these limitations. First, stands containing sugar pine on the Sequoia National Forest are generally smaller in extent, occur at higher elevations, and are less continuous than those farther north. Meadows in the Deep Creek/Schultz Creek area (6,000 to 7,000 feet elevation) are in frost pockets and low temperatures may be inhibiting spore production and infection of both pine and Ribes. Second, there is more inherent genetic resistance to the rust in sugar pines on the Sequoia than in pines farther north. The combination of less than ideal climate and less genetic susceptibility to the disease may limit the disease locally.

In general, characteristics of the disease on the Sequoia are much as would be expected from similar data collected on the rust in the northern Sierra Nevada. Two differences are that, in some areas (Packsaddle Creek/Bear Creek area in particular) rust cankers are common 30 to 40 feet high in the trees, and occur on trees at ridgetop some distance from apparent stream bottom influence. This means that small sawtimber trees can be killed, and that rust hazard -- if based on stream influence -- may be more difficult to determine.

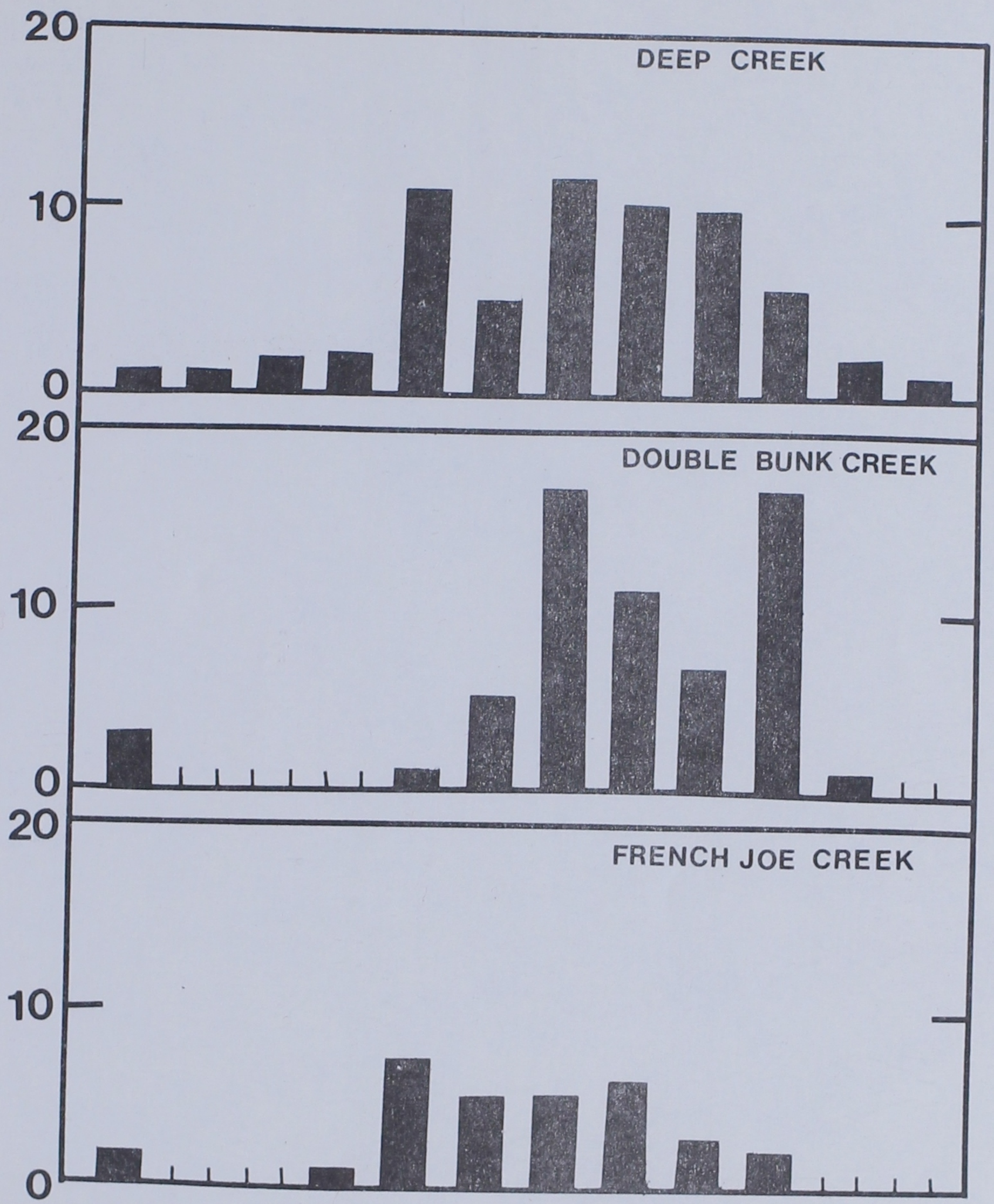

FIGURE 6. Blister rust canker incidence, by year of wood infected, at Deep Creek, Double Bunk Creek, and French Joe Creek on the Sequoia National Forest.

MANAGEMENT ALTERNATIVES

Various strategies are available to the resource manager to reduce or mitigate current and potential impacts of white pine blister rust on the sugar pine resource. The presence of the disease, or potential for disease, does not preclude the management of sugar pine to meet recreational, esthetic, or wood production objectives. The following management alternatives are approaches which are available to the Forest to be parts of an integrated pest management program.

1. No Change in Present Managment. Blister rust will likely spread and intensify in areas already infested, resulting in accelerated loss of seedling and sapling-size sugar pines. New rust cankers will continue to develop sporadically in the lower crowns of larger trees during favorable rust-years until shading and self-pruning of the lower 16 feet of the crown occurs. Sugar pine will continue to reproduce naturally in infested areas, but the amount of sugar pine in the future mixed conifer forest will decrease to levels which may not be adequate to maintain sugar pine as a significant component. The disease will spread to non-rust-resistant sugar pines planted in areas currently infested, and losses unacceptable to the Forest may occur.

2. Sanitation/Precommercial Thinnings. Sugar pines with nonprunable bole cankers or with branch cankers within 4 inches of the bole are lethally infected and should be removed in sanitation thinnings or in conjunction with regularly scheduled thinnings. Removal of infected trees will not reduce the risk of leave trees becoming infected, but would remove non-productive competing trees and would possibly release those trees with a better chance of reaching merchantable size. Only uninfected trees should be considered as candidate leave trees during precommercial thinnings. These leave trees may subsequently become infected, but are likely to reach commercial size before cankers kill them.

3. Pruning. Most blister rust infections occur within 16 feet of the ground because of favorable microclimatic conditions. Pruning of all lower branches removes the needle-bearing surface of the tree that is most vulnerable to infection. Non-lethally infected trees (those without bole cankers in the lower 16 feet of the bole and those without branch cankers within 4 inches of the bole) could be pruned of all branches from the ground up to about 16 feet on larger trees and pruned to leave a 30% live crown ratio on smaller trees. Pruning of branch cankers will prevent the fungus from reaching the bole and killing the tree. This will reduce the mortality which will result from these current branch and bole cankers. The cutting of main stems below discernible cankers (i.e., prunable bole cankers) would "save" the tree from that particular canker. However, we observed very few instances where it would be feasible. Most trees recorded as having a prunable bole canker also had lethal or lethal nonprunable branch cankers lower in the crown. Pruning of bole cankers may be more feasible in plantations. The branch pruning of selected, lightly-infected sugar pines during precommercial thinning may allow a stand to reach merchantable size.

Pruning is expensive and its practical use as a control measure may be limited by economic considerations. Pruning may not be applicable in heavily-infested areas such as Double Bunk Meadow or French Joe Meadow because of the lack of economic justification. Furthermore, pruning is no guarantee that a tree will not subsequently become lethally infected.

4. Regeneration. The presence of the rust, or its potential for occurrence in parts of the Forest not now infested, will not completely eliminate sugar pine as a component of the mixed conifer forest. Forest sites vary greatly in suitability for blister rust occurrence and intensification. The most useful indicator of future rust potential for a particular site is the level of rust that is currently present. In addition, the rust potential, or rust hazard, of a particular site is determined by 1) the topography, which influences the microclimatic conditions present, and by 2) the presence or absence of the hosts, sugar pine and Ribes.

Three levels of rust hazard -- low, moderate, and high -- can be distinguished. Low hazard sites are those where either sugar pine, Ribes, or both are absent and where the environment is generally unfavorable for infection of the host by the fungus. Unfavorable environments would include dry mid-slope or ridge top areas away from the influence of stream bottoms or wet meadows. Low hazard sites are also those sites where both hosts are present, but rust is absent and the environment is unfavorable. Sugar pines could be planted on low hazard sites with minimal risk of subsequent infection. However, site preparation and planting may so alter the site that its hazard rating may change.

High hazard sites are those where blister rust is currently present on sugar pines and/or Ribes and where climatic conditions are favorable for rust incidence, as in moist, stream bottom sites and meadows. Sugar pines susceptible to the disease should not be planted in areas where blister rust is now present. Rust infections will occur sporadically on these high hazard sites during favorable rust years. Rust resistant sugar pines could be planted with little risk of infection.

Moderate hazard sites possess a wide gradation of characteristics, such as cool, moist sites where sugar pines and Ribes are not now infected, or mid-to-upper slope sites where rust is present, but at low levels. Management strategies for regenerating sugar pine should be developed on the basis of site characteristics and District or Forest objectives. Strategies on moderate hazard sites take into account the potential risk in managing sugar pine, and include: planting a mix of species rather than pure sugar pine, increasing stocking levels to minimize potential loss, reducing brush competition, utilizing rust-resistant stock if available, and increasing surveillance for the disease.

Before sugar pine is planted in any area on the Forest, the area should be thoroughly scouted for blister rust infection levels on natural sugar pines in the vicinity, or the Forest should request a biological evaluation for rust potential from FPM. Existing sugar pine plantations on the Forest should be inspected annually for the presence of blister rust

and an evaluation requested from Forest Pest Management if assistance is needed. Recognition of the disease can be difficult. The Forest or the Districts should request training on surveillance from the Forest Pest Management Staff.

5. Integrate Treatments. Alternatives 2, 3 and 4 are not mutually exclusive. They can be used separately or in combination in various portions of the Forest to produce the results needed to meet stand objectives. Current sugar pine management practices can be continued on low hazard sites with little risk of blister rust impact. Some losses of sugar pines on high hazard sites are to be expected. These losses can be minimized by removing infected trees during sanitation and pre-commercial thinnings, by pruning infected branches, and by encouraging regeneration of species other than sugar pine. The impact of the disease on moderate hazard sites should be minimal if the potential for future rust impact is considered in management plans and objectives. More importantly, stands must be monitored aggressively for blister rust incidence to ensure that they can be treated before they become so diseased that they must be regenerated.

APPENDIX

A. TREE DIAMETER CLASS

The following six classes of tree dbh (diameter at breast height) ranges were designated:

DBH CLASS	DBH RANGE	
1	< 1.0"	seedlings
2	1.0 - 5.9"	saplings
3	6.0 - 11.9"	poles
4	12.0 - 17.9"	small sawtimber
5	18.0 - 25.9"	sawtimber
6	26.0" +	large sawtimber

B. CANKER CLASS

The following six classes of rust cankers, based on the position of the cankers in the tree, were designated:

1. Prunable bole canker: At a height 16 feet or less from the ground, and in the upper one third of live crown.

2. Nonprunable bole canker: At a height greater than 16 feet from the ground and/or in the lower two thirds live crown.

3. Nonlethal branch canker: Closest canker margin occurs 24 inches or more from the main bole.

4. Lethal prunable branch canker: Closest canker margin occurs between 4 and 24 inches from the main bole; the canker occurs in the lower two-thirds of the live crown and occurs 16 feet or less from the ground.

5. Lethal nonprunable branch canker: Canker occurs between 4 and 24 inches from the main bole; the canker occurs in the upper one-third live crown, and/or greater than 16 feet in height from the ground.

6. Lethal branch canker: Closest margin occurs within 4 inches of the main bole.

C. BLISTER RUST INFECTION CENTERS, LOCATED JULY, 1983

LOCATION	LEGAL DESCRIPTION TOWNSHIP	RANGE	SECTION
HUME LAKE RD			
Bacon Meadow	14 S	28 E	2
Tenmile Creek	14 S	28 E	1
TULE RIVER RD			
Peppermint Creek	21 S	32 E	20
Bear Creek	21 S	31 E	3
Boulder Creek Tributary	20 S	31 E	36
HOT SPRINGS RD			
White River Tributary	24 S	31 E	15
Deep Creek	24 S	32 E	30
Bull Run Creek Tributary	24 S	32 E	20
Schultz Creek	24 S	32 E	19
Packsaddle Creek #1	23 S	31 E	1
Packsaddle Creek #2	23 S	31 E	14
Starvation Creek #1	23 S	31 E	9
Starvation Creek #2	23 S	31 E	16
Horse Meadow Creek	22 S	31 E	34
GREENHORN RD			
Bear Creek	26 S	32 E	6
Shirley Peak	25 S	32 E	32
Slick Rock Creek	25 S	32 E	17